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ATTORNEY DOCKET NO. 101,931  
page 1 of 3

CERTIFICATION UNDER 37 C.F.R. § 1.10

I hereby certify that this New Application Transmittal and the documents referred to as enclosed therein are being deposited with the United States Postal Service on this date November 16, 1998 in an envelope as "Express Mail Post Office to Addressee" Mailing Label No. EL158525818US to the Assistant Commissioner for Patents, Washington, D.C. 20231.

Gregory S. Rosenblatt

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**APPLICATION TRANSMITTAL UNDER 37 C.F.R. § 1.53(b)**

Transmitted herewith for filing under 37 C.F.R. § 1.53(b) is the patent application of:

Inventor(s):

**JOHN F. BREEDIS  
RONALD N. CARON  
CARL L. DEPPISCH**

For: "STRESS RELAXATION RESISTANT BRASS"

1. Type of Application

☒ Original    ☐ Continuation    ☐ Divisional    ☐ Continuation-In-Part

2. Benefit of Prior Foreign Application(s) (35 U.S.C. § 119)

- ☐ The new application being transmitted claims the benefit of  
☐ prior foreign application serial no. \_\_\_\_\_, filed on \_\_\_\_\_ in  
\_\_\_\_\_ (country); or  
☐ PCT international application designating at least one country other than the U.S.  
application serial no. \_\_\_\_\_, filed on \_\_\_\_\_.

A certified copy is ☐ enclosed or ☐ on file in the prior application.

3. Benefit of Prior U.S. Application(s) (35 U.S.C. § 120)

- ☐ The new application being transmitted claims the benefit of prior copending U.S. application(s):  
Serial no. \_\_\_\_\_, filed on \_\_\_\_\_.

4. Papers Enclosed Which Are Required for Filing Under 37 C.F.R. § 1.53(b)

20	page(s) of Specification
4	page(s) of Claims, having 18 claims, including 2 independent and 16 Dependent claims
1	page(s) of Abstract
4	sheet(s) of <input type="checkbox"/> formal <input checked="" type="checkbox"/> informal Drawings

5. Additional Papers Enclosed

- ☐ Preliminary Amendment  
☐ Information Disclosure Statement  
☐ Form PTO-1449  
☐ Copies of Cited Art  
☐ Priority Document and Certified Copy  
☐ Form PTO-1595 (Assignment Recordation)

6. Declaration

A **SIGNED** declaration is [x] enclosed [ ] not enclosed.

7. Assignment

An Assignment is [ X ] enclosed [ ] not enclosed

[ X ] Enclosed is a recordation form and an assignment of the invention to OLIN CORPORATION, a corporation of the State of Virginia.

8. Small Entity Status

- ☐ A verified statement claiming small entity status:  
☐ is enclosed.  
☐ was filed in prior application \_\_\_\_\_ and such status is still proper and desired.

9. Fee Calculation (37 C.F.R. § 1.16) -

CLAIMS AS FILED					
	Number Filed		Number Extra	Rate	Basic Fee \$790.00
Total Claims	18	-20	-0-	\$22.00	\$ -0-
Independent claims	2	-3	-0-	\$82.00	\$ -0-
Multiple Dependent claims, if any:				\$270.00	-0-
Total					\$ 790.00
Reduction for small entity by 50%					---
TOTAL FILING FEE					\$ 790.00

05192766-111603

10. Method of Payment of Fees

☐ Check in the amount of \$ \_\_\_\_\_

☒ Charge Account No. 23-1665 in the amount of \$ 790.00

11. Authorization to Charge Additional Fees

The Commissioner is hereby authorized to charge any additional fees which may be required under 37 C.F.R. 1.16, 1.17, and 1.18, or credit any overpayment to Account No. 23-1665.

12. Correspondence

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Date: November 16, 1998

Attorney Docket  
101,931

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STRESS RELAXATION RESISTANT BRASS

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1. Field of the Invention

This invention relates to zinc-containing copper alloys (typically referred to as brass). More particularly, the resistance of brass to elevated temperature stress relaxation is increased by a controlled addition of alloying elements.

2. Description of Related Art

Throughout this patent application, all compositions are in weight percent, unless otherwise specified.

Alpha brasses, are single phase alloys of copper and zinc that contain up to 39% of zinc. The alloys are characterized by good formability, moderate strength, modest electrical conductivity and low cost. Their combination of strength, formability and electrical conductivity suit the alpha brasses for manufacture into electrical connectors used in appliance and automotive applications.

A limitation on the use of alpha brasses in certain connector applications is inadequate resistance to stress relaxation when the connector operating temperature is significantly above room temperature (nominally, room temperature is 20°C). The connector operating temperature is affected by both the ambient operating temperature and resistance heating ( $I^2R$ ) from the electrical current carried through the connector.

In one method of manufacturing an electrical connector, a wrought sheet of copper alloy is formed into a cantilever spring contact contained within a hollow box. Electrical

continuity of a circuit between the connector's spring contact and a removable blade is assured when a contact force between the spring contact and the inserted blade is maintained at above a design minimum force. Under these conditions, the connection is electrically transparent.

Over time, and more rapidly at elevated temperatures, stress relaxation weakens the contact force between the cantilever spring contact and the blade and may eventually lead to connector failure through an unacceptably low contact force. It is a primary objective of electrical connector design to maximize the contact force between the cantilever spring contact and the blade to maintain a good electrical conductivity path through the connection.

The loss of more than 30% of the originally imposed stress (70% stress remaining) at the product design life (typically 3,000 hours for automotive connectors) is one commonly applied criterion for alloy selection.

Alpha brasses such as copper alloy C240 (nominal composition 78.5%-81.5% copper, balance zinc) and copper alloy C260 (nominal composition 68.5%-71.5% copper, balance zinc) satisfy the 30% loss of originally imposed stress criterion at temperatures only up to about 75°C, well below the 125°C-150°C highest anticipated service application temperature for a number of under-the-hood automotive applications.

The addition of other alloying elements to an alpha brass have, typically, not led to an increase in stress relaxation resistance without a significant detrimental effect on other alloy properties, such as conductivity or

- 60 formability. For example, copper alloy C688 (nominal composition 22.7% zinc, 3.4% aluminum, 0.4% cobalt and remainder copper) has a 75°C application capability, the same as copper alloy C240. While copper alloy C240 has an electrical conductivity of 32%, copper alloy C688 has an
- 65 electrical conductivity of only 18% IACS. IACS stands for International Annealed Copper Standard and assigns "pure" copper an electrical conductivity value of 100% IACS at 20°C.

- The addition of tin to copper alloy C220 (nominal composition 89%-91% copper, balance zinc) forms copper alloy
- 70 C425 (nominal composition 9.5% zinc, 1.8% tin, balance copper). Copper alloy C425 has improved stress relaxation resistance enabling the alloy to be formed into connectors having an application temperature of 125°C. This advantage is offset by a large decrease in electrical conductivity,
- 75 from 44% IACS for copper alloy C220 to 28% IACS for copper alloy C425.

- United States Patent No. 4,362,579 entitled "High-Strength-Conductivity Copper Alloy" by Tsuji is incorporated by reference in its entirety herein. The patent recites a
- 80 copper alloy that is disclosed as having a combination of high strength, excellent electrical conductivity, corrosion resistance and spring qualities. The copper base alloy contains 0.4-8% nickel, 0.1-3% silicon, 10-35% zinc, concomitant impurities and the remainder is copper. The
- 85 electrical conductivity of the disclosed alloys is relatively low, ranging from 19.1% IACS to 21.2% IACS. Additionally, the required addition of silicon typically decreases hot workability, electrical conductivity and formability.

United States Patent No. 5,820,701 entitled "Copper Alloy and Process for Obtaining Same" by Bharghava discloses, in one embodiment, a copper alloy that consists essentially of 1.0% - 4.0% tin, 9.0% - 15.0% zinc, 0.01% - 0.2% phosphorous, 0.01% - 0.8% iron, 0.001% - 0.5% nickel and/or cobalt and the balance essentially copper. The disclosed copper alloys contain a minimum of 1% of tin.

There remains, therefore, a need for an alpha brass base alloy having an electrical conductivity in excess of 25% IACS and sufficient resistance to stress relaxation that a connector formed from the alloy has a 3,000 hour operating life in the 125°C-150°C temperature regime.

#### SUMMARY OF THE INVENTION

Accordingly, it is an object of the invention to provide an alpha brass base alloy with improved resistance to stress relaxation and an electrical conductivity in excess of 20% IACS. It is feature of the invention that controlled amounts of nickel, tin and phosphorus are added to the base alloy. Another feature of the invention is that the alloys of the invention are capable of forming a uniform and fully recrystallized microstructure. This microstructure is characterized by a very fine grain structure with a uniform dispersion of fine phosphide particles.

Among the advantages of the alloys of the invention are that the alloys have good resistance to stress relaxation at temperatures of up to 125°C, and in certain embodiments, the resistance to stress relaxation is significant at temperatures of up to 150°C. Another advantage of the alloys

of the invention is that the electrical conductivity is not significantly reduced below that of a non-modified alpha brass. Further, the alloys have good bend formability and relatively high yield strength. The alloys of the invention are particularly suitable for forming electrical connectors that are exposed to elevated temperature, such as connectors for automotive applications.

In accordance with the invention, there is provided a modified brass alloy that consists essentially of from 2% to the maximum of zinc that maintains an alpha brass microstructure, from 0.2% to 2% of nickel, from 0.15% to 1% of tin, from 0.03% to 0.35% of phosphorus and the balance is copper and inevitable impurities.

The objects, features and advantages recited above will become more apparent from the specification and drawings that follows.

#### IN THE DRAWINGS

Figure 1 graphically illustrates a nickel to phosphorous content ratio in accordance with a preferred embodiment of the invention.

Figure 2 illustrates the directionality of a rolled copper alloy strip.

Figure 3 graphically illustrates the effect of zinc content on the electrical resistivity factor for zinc (in micro-ohm.cm/wt.% zinc) in a copper alloy.

Figure 4 illustrates in block diagram a method for processing alloys of the invention.



DETAILED DESCRIPTION

The alloys of the invention have an alpha brass base. Prior to the addition of alloying elements, the alloy is a mixture of copper and up to 39% of zinc. Controlled amounts of nickel, tin and phosphorus are added to the alpha brass base alloy.

Table 1 illustrates an interaction between nickel, phosphorus and tin when added to copper. While the properties are recorded for a zinc-free alloy, the same interaction is predicted in the alpha brass base alloys of the invention.

An addition of nickel alone, at a level of up to about 4%, has a relatively minor impact on the mechanical properties of the copper alloy and degrades electrical conductivity. When combined with an addition of phosphorus and tin, sufficient nickel is required to interact with both the phosphorus and tin. Therefore, the alloys of the invention contain as a minimum 0.2% of nickel. If the nickel content is excessive, electrical conductivity is detrimentally affected and, therefore, the maximum nickel content is limited to 2%. Preferably, the nickel content is between 0.3% and 1.0% and most preferably between 0.4% and 0.7%.

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**TABLE 1**  
**NICKEL, PHOSPHORUS, TIN CONTRIBUTIONS**  
**(Zinc-free Alloys, Cold Roll and Relief Anneal (150°C) Temper)**

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ALLOY (plus Copper)	YIELD STRENGTH (ksi)	%IACS	%STRESS REM. 150°C X 3000 hours
1 Ni	55	58	36
1 Ni - 1 Sn	67	40	80
2 Ni - 2 Sn	79	25.4	80
1 Ni - 0.05P	57	60	66
1 Ni - 0.2 P	67	77	70
0.5 Ni - 0.1P	63	78	71
0.25 Ni - 0.25 Sn - 0.02P	64	66	79
0.5 Ni - 1 Sn - 0.1P	74	47	79

Phosphorus reacts with the nickel to form a nickel phosphide that increases the strength of the alloy.

Precipitation of nickel phosphide from the copper alloy matrix also leads to an increase in electrical conductivity. In the absence of nickel, a phosphorous addition would reduce electrical conductivity and have a minimal, if any, effect on strength.

The strength increases as a function of the phosphorus content. Below about 0.03%, there is insufficient phosphorus to react with the nickel. Above about 0.35%, there is an excess of phosphorus resulting in the formation of coarse phosphides. Accordingly, the phosphorus content of the alloys of the invention is between 0.03% and 0.2%.

190 Preferably, the phosphorus content is between 0.05% and 0.18% and most preferably between about 0.08% and 0.12%.

The increase in both strength and electrical conductivity is most effective when the ratio, by weight, of nickel to phosphorous is in the range of:

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$$\text{Ni:P} = 3.5:1 \text{ to } 7.5:1$$

More preferably, the ratio is in the range of 4:1 to 6:1 and most preferably about 5:1.

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With reference to Figure 1, the composition box for the nickel and tin content of the alloys of the invention is bounded by a minimum phosphorous content line 100, a maximum phosphorous content line 102, a minimum nickel content line 104 and a maximum nickel content line 106. The preferred nickel:phosphorous ratio is bounded by 3.5:1 ratio line 108 and 7.5:1 ratio line 110.

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Referring also to Table 1, alloy X (1% Ni, 0.05% P) is outside the preferred ratio and has both a lower yield strength and a reduced resistance to stress relaxation than either alloy Y (1% Ni, 0.2% P) or alloy Z (0.5% Ni, 0.1% P).

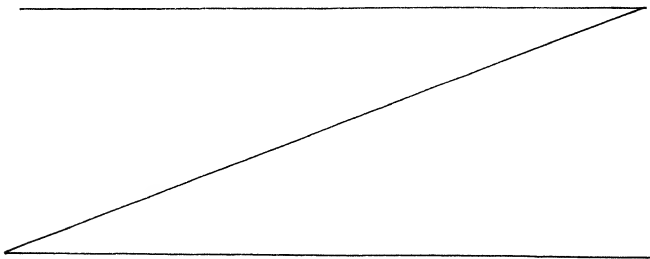
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Tin increases the strength and stress relaxation resistance of the alloy, but reduces electrical conductivity. Below about 0.15% of tin, the increase in strength is minimal. Above about 1% tin, the detrimental decrease in electrical conductivity leads to a less than satisfactory alloy and resistance to stress relaxation is not significantly further enhanced. Accordingly, the tin content of the alloys of the invention is between about 0.15% and 1%.

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Preferably, the tin content is between 0.2% and 0.7% and most preferably, the tin content is between 0.25% and 0.6%. It is a combination of nickel and tin that effectively improves the resistance of the alloy to elevated temperature stress relaxation.

Zinc contributes additional strength to the alloy. By increasing the zinc content, a smaller cold rolling reduction to final gauge is required after the last in process anneal to achieve a desired strength. As a consequence, formability at a particular strength is enhanced with zinc present and improves further with an increasing zinc content. The effect of the zinc addition on the amount of cold work needed to reach 70 ksi yield strength is recorded in Table 2. The bend formability, recorded as minimum bend radius as a function of thickness (MBR/t), is recorded in both the good way (gw) and bad way (bw) orientation. MBR is the minimum radius of a mandrel or die about which a copper alloy strip can be bent to a 90° bend without introducing fracture of the outer surfaces of the bend.



**TABLE 2**  
**INFLUENCE OF ZINC CONTENT UPON**  
**REQUIRED COLD WORK AND RESULTING FORMABILITY**

ALLOY (plus Copper)	% COLD ROLLING	YIELD STRENGTH (Relief Annealed) (ksi)	90°MBR/t gw/bw
1 Ni - 0.1P	60	63	1.2/1.2
0.5Ni - 1 Sn - 0.1P	60	74	1.4/2.3
10Zn-0.5Ni-0.3Sn-0.0.1P	40	70	0.3/0.3
20Zn-0.5Ni-0.5Sn-0.1P	20	70	S/S

S = sharp bend, MBR/t of less than 0.1.

Directionality is defined with reference to Fig. 2. A sheet 10 of a desired copper alloy is reduced in thickness by passing through rolls 12 of a rolling mill. The copper alloy sheet 10 then has a longitudinal axis 14 along the rolling direction that is perpendicular to an axis 16 about which the rolls 12 rotate. The transverse axis 18 of the copper alloy sheet 10 is perpendicular to the longitudinal axis 14.

Spring contacts formed from the copper alloy sheet and oriented parallel to the rolling direction are referred to as having a good way orientation and bend movement is in the longitudinal direction. Spring contacts having an orientation transverse to the rolling direction are referred to as having a bad way orientation and bend movement is in the transverse direction.

The zinc addition to the alloy significantly contributes to the successful manufacture of connectors formed over a smaller tool radius at a given strength.

Increasing the zinc content decreases the thermal stability of the brasses of the invention as manifest by the percent stress remaining at a fixed time and temperature.

265 With reference to Table 3, with about 10% zinc, the highest application temperature of an alloy analyzed as containing 10.2% zinc, 0.50% nickel, 0.30% tin, 0.10% phosphorous and the balance copper ("Inventive Alloy A"), using 30% of the initial stress lost criterion, is 150°C. When the zinc  
270 content is doubled to about 20%, the highest application temperature of an alloy analyzed as containing 19.8% zinc, 0.5% nickel, 0.51% tin, 0.11% phosphorus and the balance copper ("Inventive Alloy B") is less than 150°C, but above 125°C. As further illustrated in Table 3, the brasses of the  
275 invention have a thermal stability improvement over both copper zinc binary alloys and modified copper-zinc alloys.

Copper alloy C510 is a phosphor bronze with a nominal composition by weight of 5% tin, 0.2% phosphorous and the balance copper. C510 is presently widely used to manufacture  
280 appliance and automotive electrical connectors; although tin bronze alloys are more costly than brass alloys due to a higher metal value, zinc is less costly than both copper and tin.

TABLE 3  
COMPARISON OF THE STRESS RELAXATION BEHAVIOR  
OF MODIFIED BRASS ALLOYS AND VARIOUS COMMERCIAL ALLOYS  
PROCESSED TO EQUIVALENT STRENGTHS

ALLOY	TEMPER	YIELD STRENGTH (ksi)	PERCENT STRESS REMAINING (after 3000 hours)			
			75°C	105°C	125°C	150°C
Cu-2.0% Sn - 0.05% P - 10.3% Zn - 1.92% Ni	CR 60%/RA	98			72	
INVENTIVE ALLOY A	CR 40%/RA	70			87	73
INVENTIVE ALLOY B	CR 20%/RA	70			84	62
Cu-10% Zn	CR 60%/RA	68		63		
Cu-30% Zn	CR 60%/RA	85		55		
C260	Hard/RA	72	70	61	48	
C688	Half Hard	78	75			
C425	ExHard/RA	75			76	54
C510	Hard/RA	72			79	48

CR = cold rolling; RA = relief anneal  
Cu - 2.0% Sn - 0.05% P - 10.3% Zn - 1.92% Ni had an electrical conductivity of 20.8% IACS

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The zinc content of the alloys of the invention ranges between 2% and the maximum zinc content that effectively maintains an alpha brass microstructure. When the zinc content is less than 2%, the strength benefit achieved by the zinc is minimal. If excess zinc is present, rather than a single phase alpha brass, a dual phase alpha plus beta brass is formed. While the  $\alpha/\alpha+\beta$  phase field boundary is about 39% for a copper/zinc binary alloy, the other alloying additions may function as zinc replacements and change the location of the  $\alpha/\alpha+\beta$  phase field boundary. Accordingly, a maximum of 35% zinc is generally preferred. More preferably, the zinc content is between 5% and 25% and most preferably between 10% and 20%.

The electrical conductivity of the copper alloys of the invention is affected by the zinc content. While an electrical conductivity of 20% IACS is acceptable for some applications, a minimum electrical conductivity of 25% IACS is preferred. Increasing the zinc content leads to a decrease in electrical conductivity. Figure 3 graphically illustrates the effect of zinc content on the resistivity ( $\rho$ ) where:

$$172.41/\rho = \text{conductivity (in \% IACS)}$$

and

$\rho = 1.68 + \gamma$  multiplied by (Zn content in weight percent), where  $\gamma$  is the resistivity factor from Figure 3. Thus, figure 3 is used to calculate the maximum zinc content that may be included in the alloy for a desired electrical conductivity.

Iron may be added to the alloy in an amount effective to increase strength up to about 0.25%. At an iron content



above about 0.25%, the iron combines excessively with the phosphorous to the detriment of nickel phosphide formation. As iron phosphides do not have the same effect on resistance to stress relaxation as nickel phosphides, excess iron leads to a decrease in resistance to stress relaxation. Preferably, the iron content is less than 0.15% and most preferably, the iron content is in the range of from 0.07% to 0.12%.

Oxygen, sulfur and carbon may be present in the alloys of the invention in amounts typically found in either electrolytic (cathode) copper or remelted copper or brass scrap. Typically, the amount of each of these elements will be in the range of from about 2 ppm to about 50 ppm and preferably, each is present in an amount of less than 20 ppm.

Other additions that influence the properties of the alloy may also be included. Such additions include those that improve the free machinability of the alloy, such as bismuth, lead, tellurium, sulfur and selenium. When added to enhance free machinability, these additions may be present in an amount of up to 2%. Preferably, the total of free machinability addition is between about 0.8% and 1.5%.

Typical impurities found in copper alloys, particularly in copper alloys formed from recycled or scrap copper, may be present in an amount of up to about 1%, in total. As a non-exclusive list, such impurities include magnesium, aluminum, silver, silicon, cadmium, antimony, bismuth, manganese, cobalt, germanium, arsenic, gold, platinum, palladium, hafnium, zirconium, indium, antimony, chromium, vanadium, titanium and beryllium. Each impurity

should be present in an amount of less than 0.25%, and  
355 preferably in an amount of less than 0.1%.

It should be recognized that some of the above-recited  
impurities, or others, in amounts overlapping the above  
specified impurity ranges, may have a beneficial effect on  
the copper alloys of the invention. For example, strength  
360 or stampability may be improved. This invention is  
intended to encompass such low level additions.

The brass alloys of the invention may be manufactured  
by any suitable process. Figure 4 schematically  
illustrates one exemplary process. The alloy is cast by  
365 any suitable process, such as commercial DC (direct chill)  
casting. Typically, the desired amounts of nickel and iron  
(if iron is required) are added to a molten copper stock  
first. The molten copper stock may be either a recycled  
copper, cathode copper or brass alloy scrap or a mixture  
370 thereof. Next, the tin is added, followed by zinc, if  
necessary, and then the more reactive phosphorous is added.

The alloy is then cast 20 and heated for hot rolling  
22. A reduction in thickness by hot rolling is typically  
on the order of from about 50% to about 99%, in thickness,  
375 and more preferably on the order of about 70% to about 80%,  
by thickness. Hot rolling is typically conducted at a  
temperature of from about 650°C to about 900°C. The hot  
rolled strip is optionally quenched following hot rolling.

If the alloy was cast 20 by strip casting, then hot  
380 rolling step 22 may be omitted.

Following hot rolling, the surfaces of the strip are  
milled to remove surface oxides. A sequence 24 of cold  
rolling 26 and annealing 28 may be conducted either once or  
multiple times to reduce the thickness of the copper alloy

385 strip by in excess of 90%. In one exemplary process, the  
strip following hot rolling has a thickness of about 0.5  
inch and following the sequence 24, a thickness of about  
0.025 inch.

Each cold rolling 26 reduction is on the order of from  
390 about 30% to about 95% by thickness. Annealing 28  
temperature ranges from about 400°C to about 850°C for  
times of from about 10 seconds to about 5 hours. If the  
annealing is in the form of a bell anneal, the lower end of  
the temperature range and longer times are employed. If  
395 the annealing is in the form of a strip anneal, the higher  
end of the temperature range and shorter times are  
employed.

Preferably, each succeeding annealing in the sequence  
24 is at a slightly lower temperature than the preceding  
400 anneal. Sequential reduction of annealing temperature  
improves control of grain size. For example, a first  
anneal may be at a temperature of 550°C, a second anneal at  
525°C and a third anneal at 450°C.

The microstructure after the first (550°C) anneal is  
405 refined but contains occasional coarse grains. These  
grains are eliminated by the subsequent annealing steps and  
the microstructures after the second (525°C) and third  
(450°C) anneals are uniform and fully recrystallized with  
very fine grains having sizes of less than 5 micrometers  
410 ( $\mu\text{m}$ ) ( $5\mu\text{m} = 0.005$  millimeter) and a uniform dispersion of  
fine phosphide particles that are less than  $0.1\ \mu\text{m}$  and  
typically smaller than  $0.05\ \mu\text{m}$ . This particulate  
microstructure is distinguished from binary copper/zinc  
brass alloys that are single phase alloys.

415 After completion of the sequence 24, a final cold  
rolling 30 reduces the brass alloy strip to final  
thickness. For a spring contact, final strip thickness is  
typically on the order or from about 0.005 inch to about  
0.02 inch. The objective of the final cold rolling 30 is  
420 to increase strength (temper) and constitutes a reduction,  
by thickness, of between about 30% and 70%, dependent on  
the desired final temper.

The final cold rolling 30, that may be anywhere  
between a 10% and a 95% reduction in thickness, is selected  
425 to achieve a desired strength, following relief annealing  
32. The amount of thickness reduction in the final cold  
rolling 30 depends on the zinc content: the higher the zinc  
content, the smaller the percent reduction required of the  
final cold rolling 30 operation. While a cold rolling  
430 reduction of between 35% and 50% may be required for an  
inventive brass alloy containing about 10% zinc, a  
significantly smaller reduction, on the order of 15%-30% by  
thickness reduction may be effective to provide the same  
level of strength to an inventive brass alloy containing  
435 20% zinc.

When the strip is at the desired final thickness, a  
relief annealing 32 at a temperature of between about 225°C  
and about 375°C for from about 1 to about 4 hours. The  
relief annealing relieves residual stresses and thereby  
440 improves resistance to stress relaxation. In addition, the  
relief annealing recovers electrical conductivity and  
improves ductility.

The brass alloys of the invention will be better  
understood from the examples that follow.

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EXAMPLES

Example 1

450 A copper alloy (designated in Table 3 as "Inventive Alloy A") having the composition of 10.2% zinc, 0.50% nickel, 0.30% tin, 0.10% phosphorous and the remainder copper was cast as a 5 kg ingot and hot rolled from around 1.8 inches in thickness to about 0.5 inch in thickness with hot rolling starting at a temperature of 850°C. Following milling, the material was cold rolled to 0.10 inch thick, 455 annealed at 550°C for two hours, cold rolled to 0.050 inch thick, annealed at 525°C for two hours, and then cold rolled to 0.025 inch thick and annealed at 450°C for two hours. The strip was then cold rolled to 0.015 inch final thickness and a final relief anneal conducted at 275°C for 460 two hours. Following the relief anneal, the alloy had a yield strength of 70 ksi, a tensile strength of 74 ksi and an elongation of 9% (for a 2 inch gauge length), all measured at room temperature.

Electrical conductivity was measured to be 36% IACS. 465 The bends were evaluated by determining the minimum radius at which 90° bends could be made without crack development and was determined to be 0.3t in both the good way and the bad way orientations. This compares very favorably with the 0.7t for good way and bad way bends for copper alloy 470 C260 processed to the same strength, a yield strength of about 70 ksi. As noted in Table 3 above, the highest anticipated service application temperature, utilizing the 30% stress lost criterion, for this alloy is slightly above 150°C.

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Example 2

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A copper alloy (designated in Table 3 as "Inventive Alloy B") having the composition 19.8% zinc, 0.50% nickel, 0.51% tin, 0.11% phosphorous and the remainder copper was cast as a 5 kg ingot and hot rolled from around 1.8 inches to 0.5 inches with hot rolling starting at a temperature of 850°C.

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Following milling, the alloy was cold rolled to 0.10 inch thick and annealed at 550°C for two hours, cold rolled to 0.05 inch thick and annealed at 525°C for two hours and then cold rolled to 0.025 inch thick and annealed at 450°C for two hours. The alloy was then subjected to a final cold roll to 0.02 inch and a relief anneal of 275°C for two hours. The room temperature tensile properties obtained were a yield strength of 70 ksi, a tensile strength of 78 ksi and an elongation of 17% (for a 2 inch gauge length).

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The electrical conductivity was measured to be 28% IACS, equivalent to both copper alloys C260 and C425 and better than copper alloy C510 that has an electrical conductivity of 15% IACS.

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The formability as measured by the minimum radius at which 90° bends could be made without crack development was determined to be near zero-dimension radius (sharp) in both the good way and bad way orientations. This formability is better than that observed for either copper alloy C260 or copper alloy C425 when at comparable strength. For comparison, copper alloy C510 in the hard, relief anneal temper, that also has a yield strength of between 70 and 75 ksi, typically has a 90° minimum bend radius of sharp in the good way but 0.8t in the bad way.

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As recorded in Table 3, the highest anticipated service application temperature, based on 30% stress lost, is in excess of 125°C, but below 150°C.

It is apparent that there has been provided in  
510 accordance with this invention a brass alloy that fully satisfies the objects, means and advantages set forth hereinabove. While the invention has been described in combination with embodiments thereof, it is evident that many alternatives, modifications and variations will be  
515 apparent to those skilled in the art in light of the foregoing description. Accordingly, it is intended to embrace all such alternatives, modifications and variations as fall within the spirit and broad scope of the appended claims.

520

IN THE CLAIMS

We Claim:

1. A brass alloy, consisting, by weight, essentially  
of:

from 2% to the maximum that maintains an alpha  
525 brass microstructure of zinc;  
from 0.2% to 2% nickel;  
from 0.15% to 1% tin;  
from 0.03% to 0.35% phosphorous; and  
the balance copper and inevitable impurities.

530

2. The brass alloy of claim 1 wherein said nickel  
and said phosphorous are present in an amount effective to  
provide a nickel:phosphorous weight ratio of between 3.5:1  
and 7.5:1.

535

3. The brass alloy of claim 2 wherein said nickel  
and said phosphorous are present in an amount effective to  
provide a nickel:phosphorous weight ratio of about 5:1.

540

4. The brass alloy of claim 2 further including  
between 0.07% and 0.12% of iron.

545

5. The brass alloy of claim 2 further including from  
about 2 ppm to about 50 ppm of oxygen, sulfur, carbon or a  
mixture thereof.

6. The copper alloy of claim 2 wherein said zinc is  
present in an amount of from 8% to 25%.



550 7. The copper alloy of claim 3 wherein said nickel  
is present in an amount of from 0.3% to 1%.

8. The copper alloy of claim 7 wherein said tin is  
present in an amount of from 0.2% to 0.7%.

555

9. The copper alloy of claim 8 wherein said  
phosphorous is present in an amount of from 0.05% to 0.18%.

10. The copper alloy of claim 6 wherein said tin is  
560 present in an amount of from 0.2% to 0.7%.

11. The copper alloy of claim 10 wherein said zinc  
content is about 10.2%, said nickel content is about 0.50%,  
said tin content is about 0.30% and said phosphorous  
565 content is about 0.10%.

12. The copper alloy of claim 10 wherein said zinc  
content is about 19.8%, said nickel content is about 0.50%,  
said tin content is about 0.51% and said phosphorous  
570 content is about 0.11%.

13. An electrical connector having a conductivity in  
excess of 25% IACS and a resistance to stress relaxation at  
a 125°C operating temperature formed from the alloy of  
575 claim 6.

14. An electrical connector having an electrical conductivity in excess of 25% IACS and a resistance to stress relaxation at a 125°C operating temperature formed  
580 from the alloy of claim 8.

15. A process for the manufacture of a copper alloy strip having an electrical conductivity in excess of 20% IACS and resistance to stress relaxation at a 125°C  
585 operating temperature, comprising the steps of:

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casting a copper alloy consisting essentially of 8%-25% zinc, 0.3%-1% nickel, 0.2%-0.7% tin, 0.05%-0.18% phosphorous and the balance copper an inevitable impurities;

590 hot rolling said copper alloy to form said copper alloy strip at a temperature in excess of 650°C for a thickness reduction of between 50% and 99%, in thickness;

repeating the sequence of cold rolling followed by annealing multiple times wherein each cold rolling step  
595 provides said copper alloy strip with a thickness reduction of between 30% and 95%, in thickness, and each sequential annealing temperature is between 400°C and 600°C;

cold rolling said copper alloy strip to final strip thickness by a reduction of between 30% and 70%, by  
600 thickness; and

relief annealing said copper alloy strip at a temperature of between 200°C and 350°C.

605 16. The process of claim 15 wherein each successive  
one of said sequential annealing temperatures is less than  
an immediately preceding one of said sequential annealing  
temperatures.

610 17. The process of claim 16 wherein said step of cold  
rolling to final thickness includes reducing the thickness  
of said copper alloy strip to within the range of 0.005  
inch and 0.02 inch.

615 18. The process of claim 17 including the further  
step of forming said copper alloy strip at final gauge into  
an electrical conductor.

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ABSTRACT OF THE DISCLOSURE

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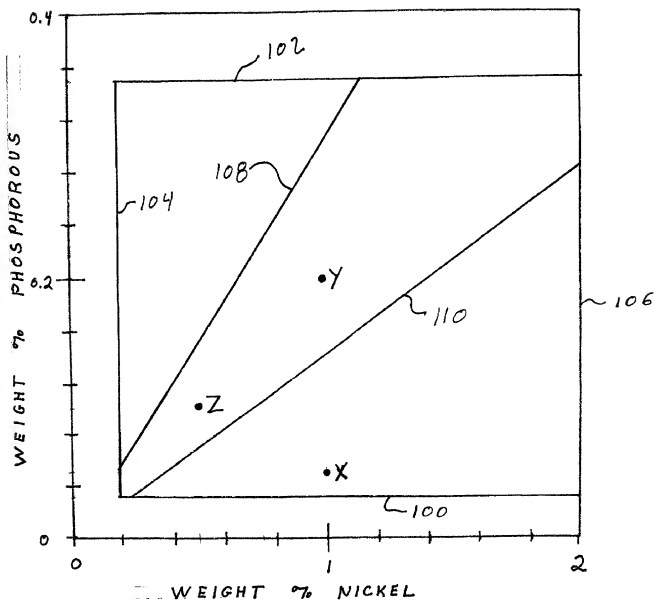
An alpha brass (copper/zinc alloy with less than 39%, by weight, of zinc) stock alloy has controlled additions of nickel, tin and phosphorous. The combination of nickel and tin increase resistance of the alloy to elevated temperature stress relaxation. As a result, spring contacts formed from alloys of the invention maintain a higher percentage of initially imposed stress at elevated temperatures, in the range of 125°C to 150°C, for significantly longer times than other brass alloys of comparable strength.

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FIG. 1



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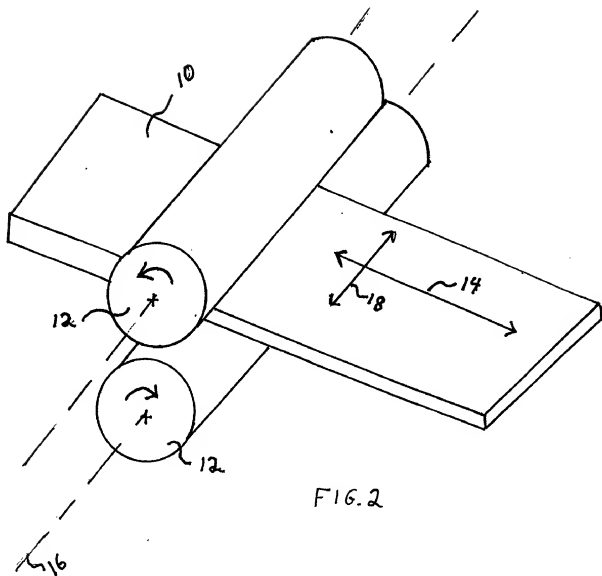
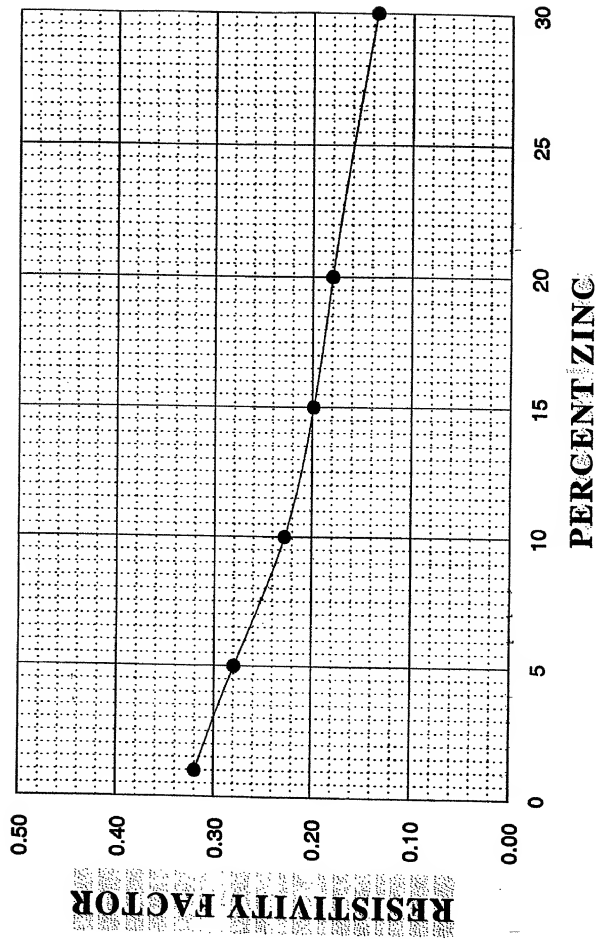


Fig. 3



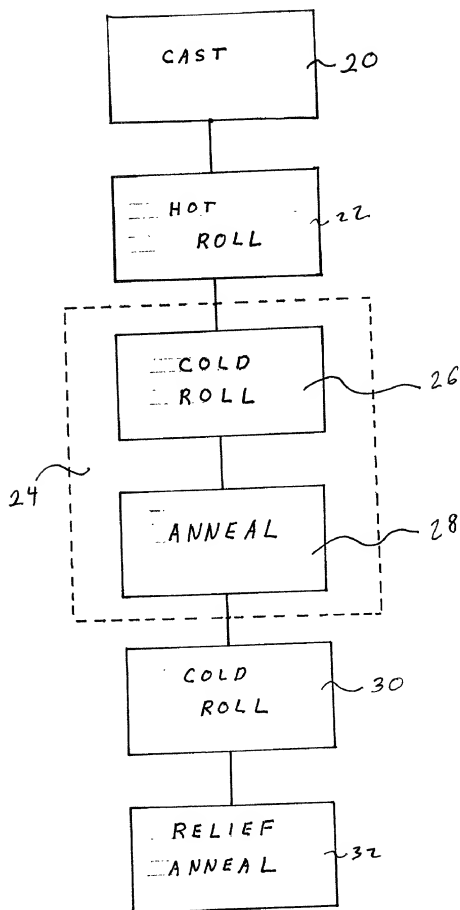


FIG. 4



**COMBINED DECLARATION AND POWER OF ATTORNEY FOR JOINT INVENTORS**

1. As below named joint inventors, we hereby declare that our addresses and citizenship are as stated below next to our names. We believe we are the original, first, and joint inventors of the subject matter which is claimed and for which a patent is sought on the invention entitled:

**"STRESS RELAXATION RESISTANT BRASS**

*11/8/88*  
*CD 11/13/88*  
*RNC 11/24/88*

the specification of which:

☒ is attached or

☐ was filed on \_\_\_\_\_ as Serial No. \_\_\_\_\_ and amended on \_\_\_\_\_.

2. We hereby state that we have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.
3. We acknowledge the duty to disclose information which is material to the patentability of this application in accordance with Section 1.56(a) of Title 37, Code of Federal Regulations.
4. ☐ Because this is a continuation-in-part application, we acknowledge our duty to disclose to the Office all information known to us to be material to the patentability as defined in 37 C.F.R. § 1.56 which has become available between the filing date of the prior application and the filing date of this continuation-in-part application.
5. ☐ We hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by us on the same subject matter having a filing date before that of the application(s) of which priority is claimed:

Country	Application Serial No.	Date of Filing (day, mo., yr.)	Priority Claimed under 35 U.S.C. § 119	
			<input type="checkbox"/> Yes	<input type="checkbox"/> No
			<input type="checkbox"/> Yes	<input type="checkbox"/> No
			<input type="checkbox"/> Yes	<input type="checkbox"/> No

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6. [ ] We hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s) that is/are listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in that/those prior application(s) in the manner provided by the first paragraph of Title 35, United States Code, § 112, we acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, § 1.56(a) which occurred between the filing date of the prior application(s) and the filing date of this application:

Application Serial No.	Filing Date	Status

7. We hereby declare that all statements made herein of our own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.
8. As named inventors, we hereby appoint the following attorneys of Wiggin & Dana to prosecute this application and transact all business in the Patent and Trademark Office connected therewith: Dale L. Carlson, Reg. No. 28,784; Todd E. Garabedian, Ph.D., Reg. No. 39,197; Thomas F. Presson, Reg. No. 41,442; Gregory S. Rosenblatt, Reg. No. 32,489; William A. Simons, Reg. No. 27,096; and William B. Slate, Reg. No. 37,238.
9. Please send all correspondence to:
- Gregory S. Rosenblatt**  
Intellectual Property Law Section  
Wiggin & Dana  
One Century Tower  
New Haven, CT 06508-1832
10. [X] As named inventors, we hereby appoint the attorney listed in paragraph 9 as our domestic representative for the invention identified in paragraph 1 with full power of substitution and revocation, to transact all business in the U.S. Patent and Trademark Office and in the U.S. courts in connection therewith. He is also designated as domestic representative on whom process or notice of proceedings affecting the application or patents issuing therefrom may be served.

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[X] We hereby authorize the U.S. attorney named in paragraph 9 to accept and follow instruction from OLIN CORPORATION as to any actions to be taken in the U.S. Patent and Trademark Office regarding this application without direct communication between the U.S. attorney and us. In the event of a change in the person from whom instructions may be taken, we will notify the U.S. attorney.

## 11. Inventor Information:

Full name of first joint inventor John F. BreedisInventor's signature *John F. Breedis*Date November 13, 1998 Citizenship USAResidence 15 Copper Kettle Road, Trumbull, Connecticut 06611P.O. Address 15 Copper Kettle Road, Trumbull, Connecticut 06611Full name of second joint inventor Ronald N. CaronInventor's signature *Ronald N. Caron*Date November 13, 1998 Citizenship USAResidence 48 Meadow Circle Road, Branford, Connecticut 06405P.O. Address 48 Meadow Circle Road, Branford, Connecticut 06405Full name of third joint inventor Carl L. DeppischDate November 13, 1998*Carl L. Deppisch*  
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This is the end of the listing of inventors.